International Civil Aviation Organization

THE SIXTH MEETING OF THE ASIA/PACIFIC GBAS/SBAS IMPLEMENTATION TASK FORCE (GBAS/SBAS ITF/6)

(Bangkok, 7- 9 May 2024)

Agenda Item 3: Updates from States/Administrations about GBAS/SBAS Implementation

Report of GBAS Proof-Of-Concept Project at Suvarnabhumi International Airport

(Presented by Japan and Thailand)

SUMMARY

This paper presents the summary of the GBAS Proof-Of-Concept (PoC) Project between Japan and Thailand. The project successfully demonstrated that the GBAS equipment operated within ICAO standards using Thailand's Ionospheric Threat Model developed from local data collection. Throughout the project, issues regarding scintillation and RF interference occurred, while changing the antenna addressed scintillation issues, further work is required to mitigate the RF interference.

1. INTRODUCTION

1.1 The GBAS Proof-Of-Concept Project was a joint technical collaboration between Japan and Thailand with the main objective to install a GBAS equipment at Suvarnabhumi International Airport and conduct experiments for deploying GBAS in a low geomagnetic latitude area that is affected by the ionospheric irregularities.

1.2 The project was initiated in 2019 by Japan's Ministry of Internal Affairs and Communications (MIC) and the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) through an industrial promotion program aimed at assisting Japanese industries in addressing social problems and challenges in Asian countries by leveraging Japan's wireless technologies.

1.3 NEC Corporation was contracted by MIC to supply the GBAS equipment and to offer technical support throughout the project. The project includes evaluation of the impacts of the ionospheric irregularities on GBAS and the development of Thailand's ionospheric threat model by the Aeronautical Radio of Thailand (AEROTHAI) with technical support from the Electronic Navigation Research Institute (ENRI) and King Mongkut's Institute of Technology Ladkrabang (KMITL). The relationship between the organizations involved is shown in Figure 1. The project's timeframe was from January 2020 to March 2024 with a summary of conducted activities in Table 1.

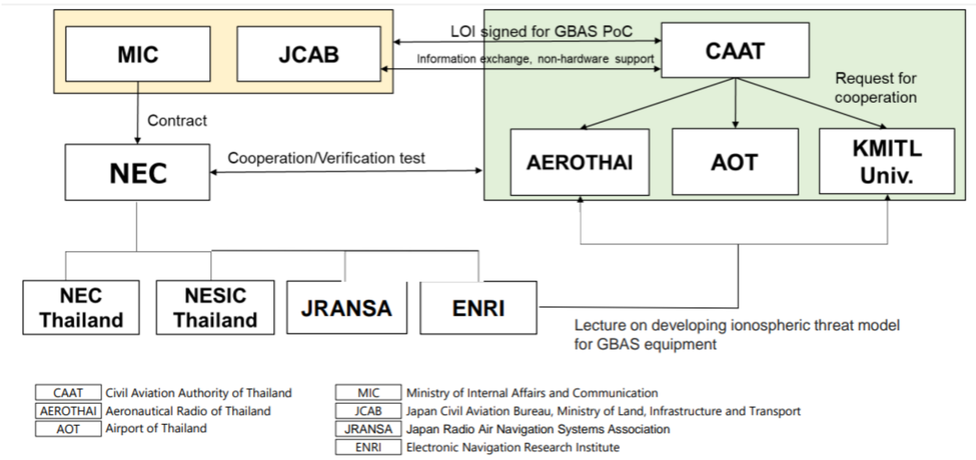

Figure 1. The relationship and organizations involved in the GBAS PoC Project

Table 1. Summary of key activities of the GBAS PoC Project

Year	Key Activities
2019	• Project proposal from MIC and MLIT (JCAB) to CAAT
2020	• Project kick-off • Letter of intent (LOI) including with TOR exchanged between MIC/JCAB and CAAT • Initial ionospheric threat model development • Construction and installation preparation • Equipment preparation
2021	• Ionospheric threat model development (continue) • Construction and installation preparation (continue)
2022	• Equipment construction, installation, and evaluation • Flight demonstration preparation • Training and technical transfer • Flight demonstration and performance evaluation
2023	• Flight demonstration and performance evaluation (continue) • Performance Analysis • Determination of practical solution for implementation
2024	• Performance Analysis (continue) • Final report development • Removal of GBAS equipment

2. DISCUSSION

<u>GBAS PoC Equipment</u>

2.1 Figure 2 illustrates the installation location and configuration of the GBAS PoC system, which includes three reference receivers (RRs), a data processing unit, a VDB (VHF Data Broadcast) transmitter, and an Ionospheric Field Monitor (IFM). Meanwhile, Figure 3 illustrates the construction layout of the reference receivers and VDB situated above the end of runway 19R at Suvarnabhumi International Airport.

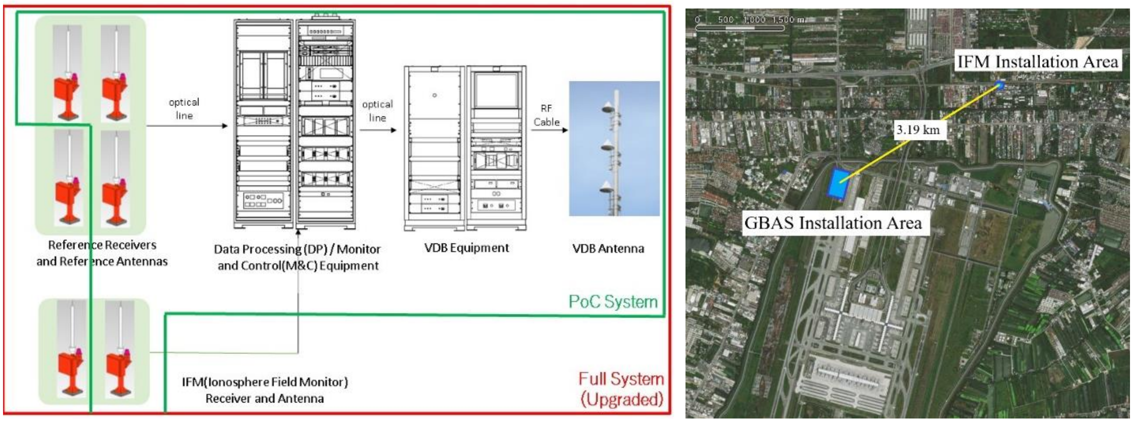

Figure 2. The GBAS PoC system configuration (left) and installation location (right)

Figure 3. Construction layout of the GBAS PoC System at Suvarnabhumi International Airport

2.2 In early 2022, the GBAS PoC equipment was fully constructed and installed at the end of runway 19R at Suvarnabhumi International Airport, as depicted in Figure 4. Furthermore, Figure 5 illustrates the Ionospheric Field Monitor (IFM) that has been installed on the campus of King Mongkut's Institute of Technology Ladkrabang (KMITL) to detect ionospheric disturbances.

Figure 4. GBAS shelter and VDB antenna (left) and RR antenna (right) installed at Suvarnabhumi International Airport

Figure 5. IFM Antenna and Receiver

Development of Ionospheric Threat Model

2.3 To evaluate the impacts of ionospheric irregularities on GBAS, the Aeronautical Radio of Thailand (AEROTHAI) developed the ionospheric threat model with technical support from the Electronic Navigation Research Institute (ENRI) and King Mongkut's Institute of Technology Ladkrabang (KMITL). The collected GPS data was analyzed to estimate the background residual ionospheric uncertainty during both ionospheric quiet and disturbed conditions. Furthermore, the ionospheric threat model development involved estimating the ionospheric delay gradient (slope), front speed (v), front width (w), and direction during the ionospheric disturbed conditions.

2.4 AEROTHAI evaluated the ionosphere characteristics in Bangkok for the years 2012, 2020, 2021, and 2022, representing both high and low solar activities. The evaluation was conducted using the single-frequency carrier-based and code-aided (SF-CBCA) method, courtesy of ENRI. The GNSS data was collected from three receivers located at different sites: Stamford International University, KMITL, and the Suvarnabhumi International Airport (01L Localizer station), as shown in the Figure 6.

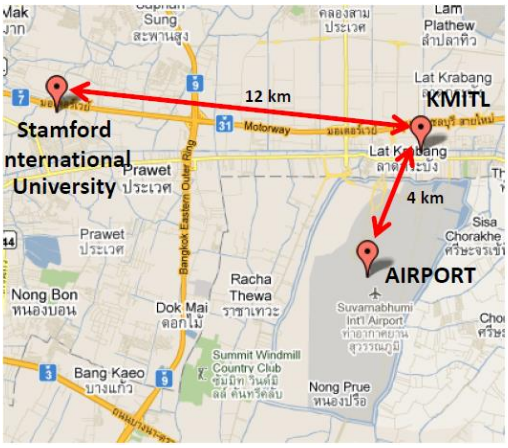

Figure 6. GNSS stations used for ionospheric threat model development

2.5 The SF-CBCA method is employed to estimate the single-difference of ionospheric delay between a pair of GNSS receivers with known relative positions. The method involves estimating float solutions using Kalman filtering and then fixing them using the double-difference of the integer ambiguity of carrier-phase measurements. The results of the method, after validating the ambiguity resolution, are summarized in Figure 7.

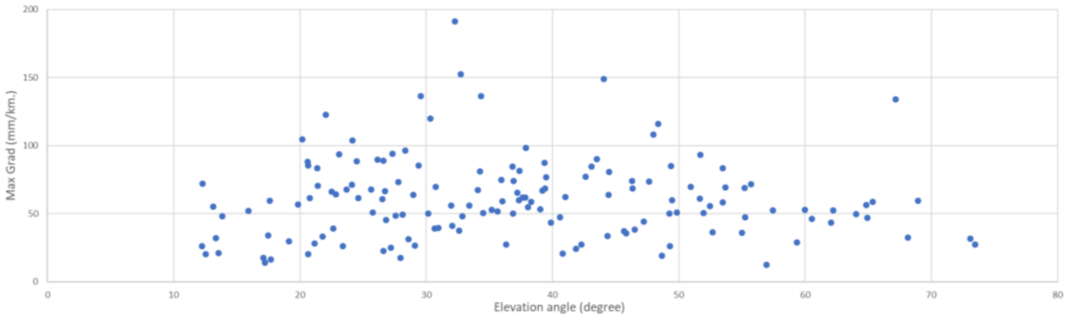

Figure 7. The ionospheric delay gradient observed during the year of 2012, 2020, 2021, and 2022

2.6 Furthermore, the front speed (v), front width (w), and direction were calculated as part of the analysis. After consulting with the ionosphere expert, the parameters for the ionospheric threat model for Bangkok are summarized in Table 2. the system. To ensure that the threat model accurately reflects the nature of ionospheric activities primarily caused by solar activity during each solar cycle, these parameters are expected to be reviewed and updated on an annual basis, as necessary.

Table 2. Ionospheric threat model parameters for Bangkok

Parameters	Range of values
Slope (g)	300 mm/km
Width (w)	4-200 km
Front speed (v)	0-300 m/s
Direction	All direction (0-360 Degree)
Depth (D)	15 m (maximum)

Training & Technical Exchange

2.7 Numerous training and technical exchanges were held throughout the project, with JCAB sharing their expertise on the training of GBAS flight procedure design techniques and practices as well as their knowledge and methods on flight inspection of GBAS; and NEC providing training on basics of GPS and the positioning techniques as well as knowledge on NEC's GBAS and how it is operated.

Figure 8. Training and technical exchanges from Japan to Thailand personnel.

Flight Demonstration Results

2.8 To conduct the flight demonstration, AEROTHAI developed eight GLS approach procedures for all four runway ends of Suvarnabhumi International Airport, with technical assistance from the Japan Civil Aviation Bureau (JCAB). Four of these GLS procedures are overlays of ILS procedures, showcasing that a single GBAS system can cover multiple runways ends. The remaining four special GLS procedures emphasize the advantages of GBAS without requiring modifications to runways or hardware configurations. Examples of GLS approach procedures are provided in Figure 9. Two procedures utilize a higher glide path angle (GPA) of 3.2 degrees for runway 19R and 01L, aiming to reduce aircraft noise emissions. The other two procedures involve a displacement of 300 meters from the existing runway threshold for runway 19L and 01R, demonstrating GBAS's capability to provide approach guidance during runway maintenance activities.

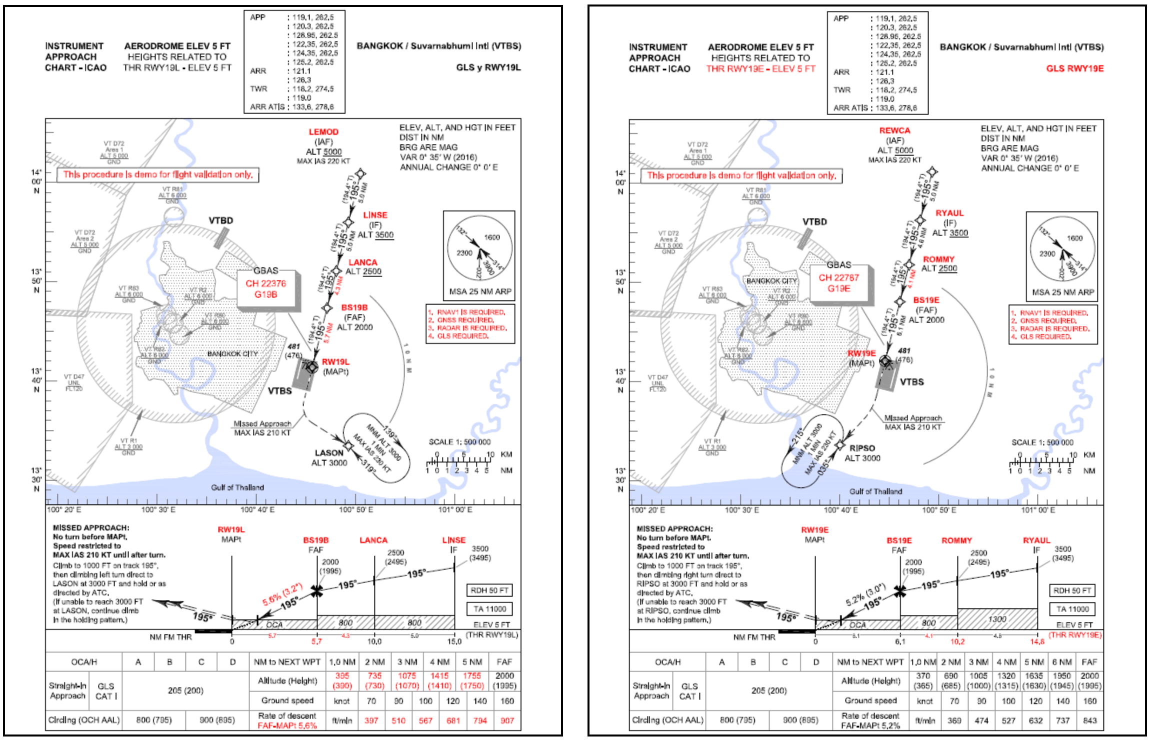

Figure 9. GLS procedure runway 19L with GPA of 3.2 degrees (left) and GLS procedure runway 19R with 300 meters of displaced threshold (right) <Not for operation>

2.9 During the period of November 2022 to January 2023, AEROTHAI conducted several GBAS flight demonstrations using their Beechcraft Super King Air 350 aircraft equipped with the GBAS Flight Inspection System (FIS), as depicted in Figure 10 (left). The aircraft performed various flight patterns, including arc flights, level runs, and normal approaches. Several parameters were evaluated during these demonstrations, including the coverage of the VHF Data Broadcast (VDB), deviation errors between GLS and ILS approaches, and radio signal interferences.

Figure 10. Flight demonstration aircraft "Beechcraft Super King Air 350" (left) and flight patterns (right)

2.10 The overall results of the demonstration indicated that the GBAS system successfully met all performance requirements. Example demonstration results can be seen in Figure 11. The VDB coverage was found to be sufficient, and the deviation error between GBAS and ILS approaches remained within acceptable limits. Additionally, the GBAS system demonstrated its ability to improve runway throughput and capacity by eliminating the need for critical or sensitive areas of the ILS during runway operations.

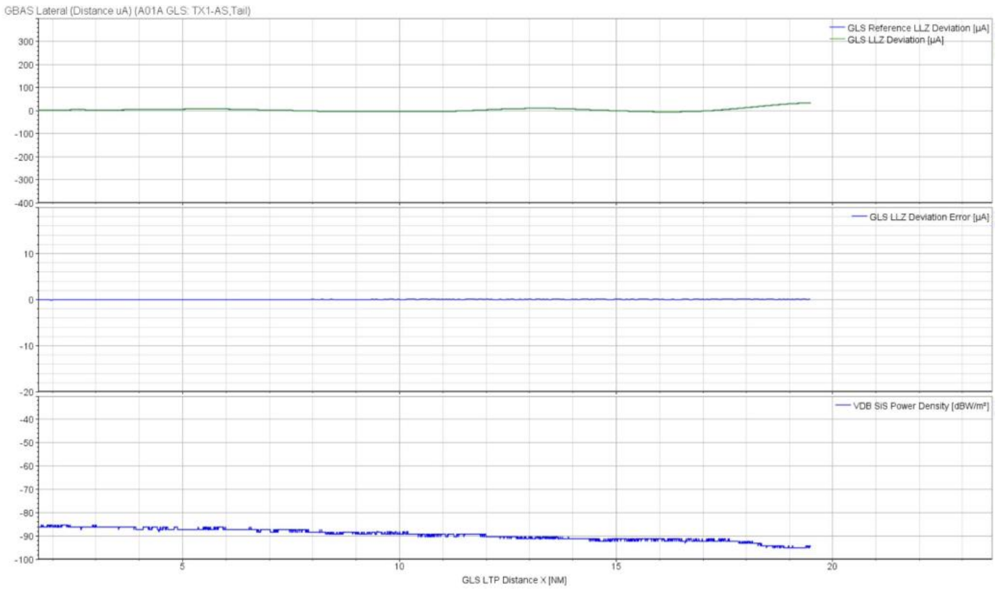

Figure 11. Example demonstration results of GLS lateral deviation (top), GLS deviation error (middle), and VDB power density (bottom)

GBAS Performance Evaluation

2.11 To analyze the performance of the GBAS PoC, performance evaluation equipment was installed in a laboratory on the rooftop of the engineering building at KMITL, approximately 4 km North-East of the GBAS PoC located at Suvarnabhumi International Airport as seen in Figure 12.

Figure 12. Location of GBAS Performance Evaluation Equipment and GBAS PoC (Left), GBAS Performance Evaluation Equipment (Middle), GNSS Antenna for Performance Evaluation (Right)

2.12 The evaluation is done by using collected GPS and GBAS data and simulating the operation of the airborne system, together with the ionospheric threat model resulting in the availability of the GBAS PoC system.

2.13 The availability of the GBAS equipment during the evaluation period was good, with the frequency distribution of the protection level occurrence for vertical and lateral errors as shown in Figure 12 and summarized in Table 3. The evaluation period was a chosen period where there were no scintillations and external interferences. The availability for the evaluation period was 99.60% within ICAO's criteria of 99 – 99.9%, with the main reason for the loss of availability being the reduction in the number of satellites.

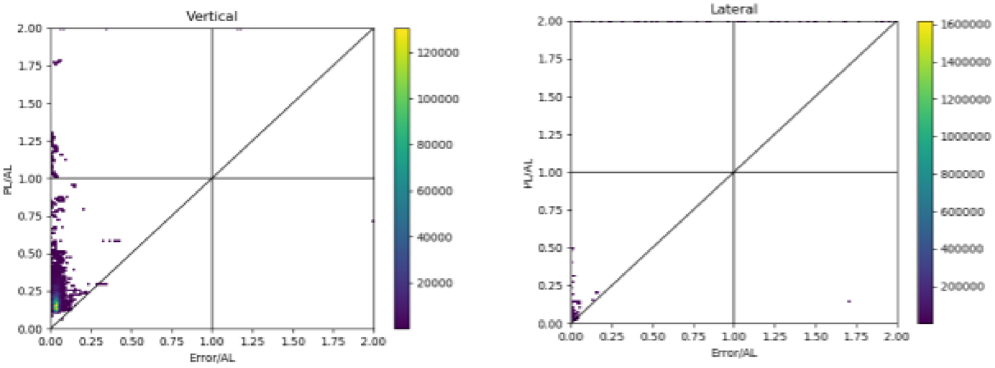

Figure 12. Stanford plot for vertical errors (left), and lateral errors (right)

Table 3. Summary of GBAS PoC Performance Evaluation

	Vertical Direction		Lateral Direction	
Total number of epochs	3,181,134			
Available	3,168,409	99.6%	3,168,665	99.61%
PL > AL	12,691	0.40%	12,325	0.39%
MI (PL < AL)	33	0.001%	143	0.0045%
HMI	1	0.000031%	1	0.000031%

Challenges and Difficulties

- Ionospheric Scintillation

2.14 During the evaluation of GBAS PoC performance, issues of ionospheric scintillation were found resulting in the absence of GNSS signals at all reference receivers, illustrated in Figure 14. Inspection of the GBAS PoC found that the equipment operated normally, however after a change of the MLA antenna of one reference receiver, using an improved antenna with increased gain, developed by the manufacturer, NEC Japan, issues from ionospheric scintillation at that antenna were less frequent. To definitively establish the change of antenna as a comprehensive solution for mitigating scintillation, further controlled trials are recommended

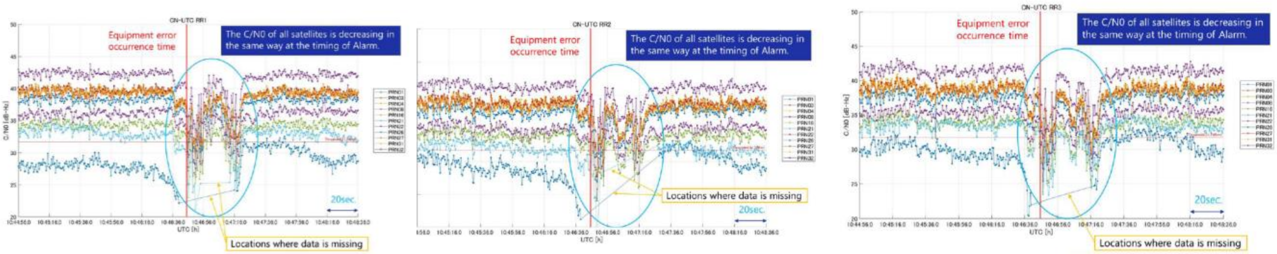

Figure 14. Example of GNSS signal absence at reference receivers during ionospheric scintillation occurrences

- RF interference

2.15 Although ionospheric scintillation issues were addressed, events of GNSS absence were still detected. Coordination with the frequency regulator in Thailand were initiated to investigate the issue resulting in discovery of GPS Jamming devices detected in local transport commuting around Suvarnabhumi International Airport.

2.16 Actions were made by CAAT in contacting e-commerce platforms in Thailand to cease and remove all GPS Jammers of the platforms. Further coordination with local police, transport authorities, frequency regulators have been initiated and will result in further inspections and enforcement of unlawful acts of GPS Jamming usage. Efforts were also put into the communication to stakeholders and the general public relating to publicize the effects on safety that GPS Jammers can have.

Conclusion

2.17 The GBAS PoC Project successfully demonstrated that GBAS operating in low geomagnetic latitude area affected by the ionospheric irregularities comply to ICAO standards. In achieving operation within the standards, local data should be collected and used to develop an ionospheric threat model that could signify the local ionosphere of the area of operations. This helps giving a more accurate bound (less conservative) of actual occurrences of the effects of the ionosphere thus providing a better performance of the installed GBAS system.

3. ACKNOWLEDGEMENT

3.1 This project was financially support by the Ministry of Internal Affairs and Communications (MIC) of Japan under the industrial promotion program.

4. ACTION REQUIRED BY THE MEETING

4.1 The meeting is invited to:

a) note the information contained in this papers; and
b) consider sharing State’s experiences on GNSS RFI unearthing and mitigation methods since more states are witnessing an increase in GNSS RF Interference
c) discuss any relevant matters as appropriate.

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